

# RF issues of operation of RT and SC cavities with a single klystron

Gennady Romanov

March 1, 2007

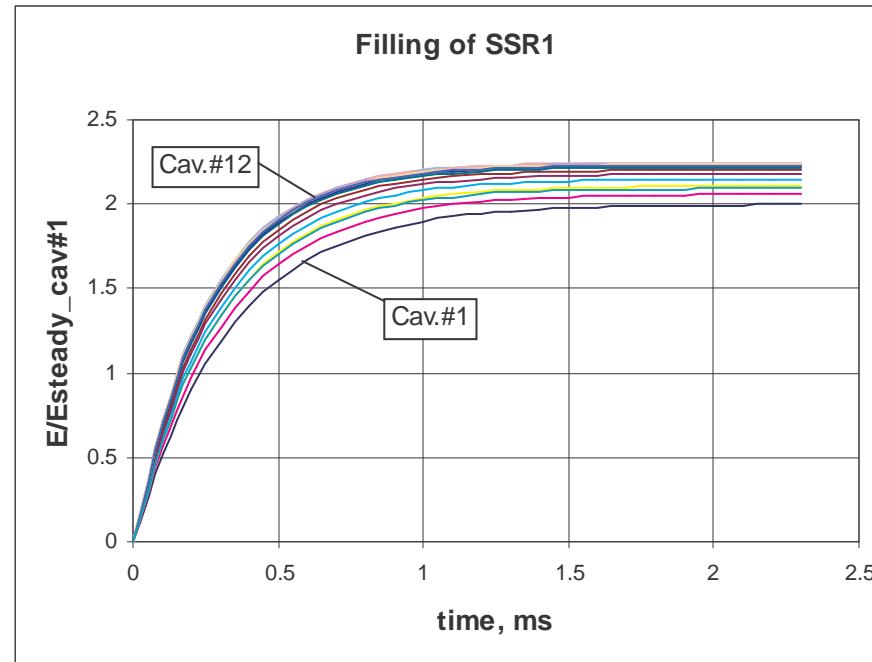
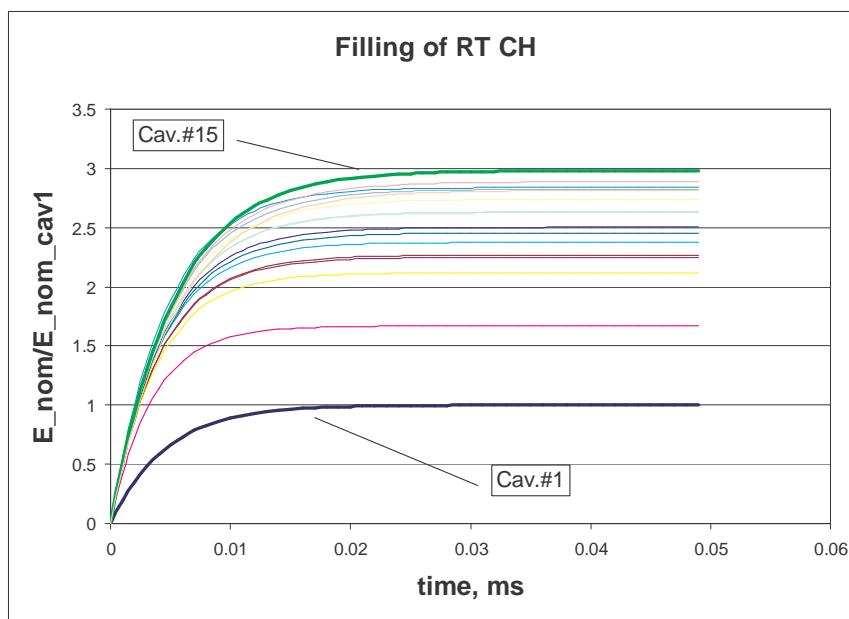
**A new table for RT CH (part of it concerning RF).  
Beam current 25 mA.**

Version from November 2006 revised February 2007							
RT CH	Q_0	Pcopper kW	Pbeam kW	Optimal Coupling	Q_loaded	tau_L mcs	Fil.time 99% field
1	9270	1.991226	0	1	4635	2.269794	20.88211
2	9662	5.681364	3.99896	1.703873	3573.392	1.749917	16.09924
3	10051	9.602462	5.29344	1.551259	3939.624	1.929264	17.74922
4	10461	12.91047	6.214523	1.481355	4215.841	2.064529	18.99367
5	10772	13.33876	7.704745	1.577621	4179.048	2.046511	18.8279
6	11078	14.19729	8.946352	1.630145	4211.935	2.062616	18.97607
7	11374	17.52655	10.15274	1.579277	4409.762	2.159494	19.86734
8	11680	19.32231	11.76513	1.608889	4477.002	2.192422	20.17028
9	11945	26.30535	14.94279	1.568052	4651.386	2.277819	20.95593
10	12220	23.79093	14.78462	1.62144	4661.561	2.282801	21.00177
11	12465	25.40959	15.48769	1.609522	4776.738	2.339204	21.52068
12	12750	29.09813	16.80597	1.577562	4946.535	2.422356	22.28567
13	13005	32.84304	18.07172	1.550245	5099.51	2.497269	22.97487
14	13271	36.38964	19.2515	1.529038	5247.45	2.569716	23.64138
15	13494	41.4155	20.71976	1.50029	5396.974	2.642939	24.31504
16	13723	39.0474	18.52162	1.474337	5546.132	2.715983	24.98704

**A new table for RT CH (part of it concerning RF).  
Beam current 10 mA.**

<b>Beam current 10 mA</b>							
RT CH	Q_0	Pcopper kW	Pbeam kW	Optimal Coupling	Q_loaded	tau_L mcs	Fil.time 99% field
1	9270	2.099206	0.94939	1.452261	3780.184	1.851185	17.0309
2	9662	5.830673	1.620467	1.277921	4241.587	2.077137	19.10966
3	10051	8.390486	1.979248	1.235892	4495.298	2.201381	20.25271
4	10461	9.430674	2.124556	1.225281	4700.978	2.302104	21.17936
5	10772	8.631133	2.479102	1.287228	4709.631	2.306342	21.21834
6	11078	9.206089	2.881648	1.313015	4789.419	2.345415	21.57781
7	11374	10.26684	3.108231	1.302745	4939.323	2.418824	22.25318
8	11680	11.30972	3.600421	1.318347	5038.071	2.467181	22.69807
9	11945	16.63397	4.752999	1.285741	5225.878	2.559152	23.54419
10	12220	15.49175	4.772158	1.308045	5294.524	2.592768	23.85347
11	12465	17.86917	5.195174	1.290734	5441.488	2.664737	24.51558
12	12750	20.20533	5.601753	1.277241	5598.88	2.741813	25.22468
13	13005	22.79511	6.022247	1.26419	5743.775	2.81277	25.87748
14	13271	26.11348	6.523311	1.249806	5898.73	2.888653	26.5756
15	13494	29.15796	7.514952	1.257732	5976.793	2.926881	26.9273
16	13723	33.61986	7.526246	1.223863	6170.794	3.021884	27.80133

## Switch RF power on. Transient fields in the cavities.



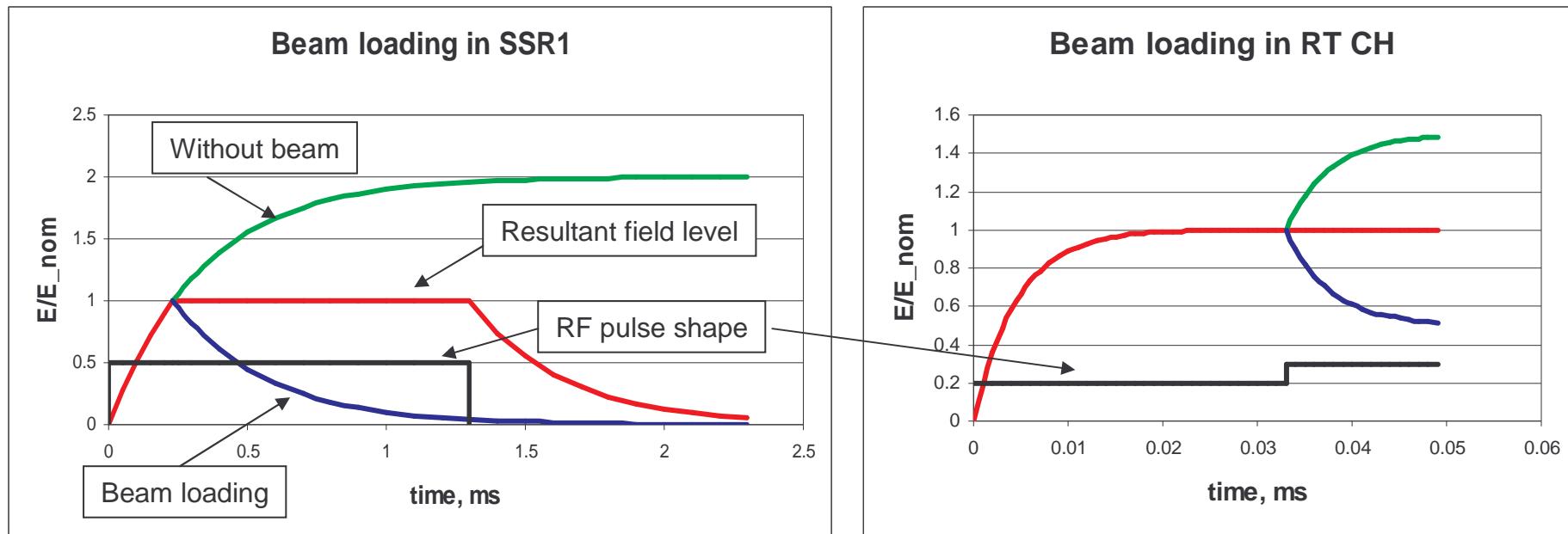
$$\text{Transient fields} \propto e^{-\frac{t}{2\tau}}$$

Time constant  $\tau = \frac{Q_L}{\omega}$ , where  $Q_L = \frac{1}{1/Q_0 + 1/Q_{ext}}$

Losses in copper: 2÷41 kW , 348 kW total  
 Beam power: 0÷21 kW, 193 kW total  
 Time constant: 0.0017÷0.0027 ms

Losses in niobium: 5 W  
 Beam power: 26÷33 kW, 568 total  
 Time constant: 0.128÷0.167 ms

## Beam loading compensation.



$$P_{\text{gen}} = P_{\text{beam}} = U_{\text{eff}} \cos\varphi I_{\text{beam}}$$

Standard cavity filling scheme to reduce filling time. Beam is turned on when field level reaches nominal value.

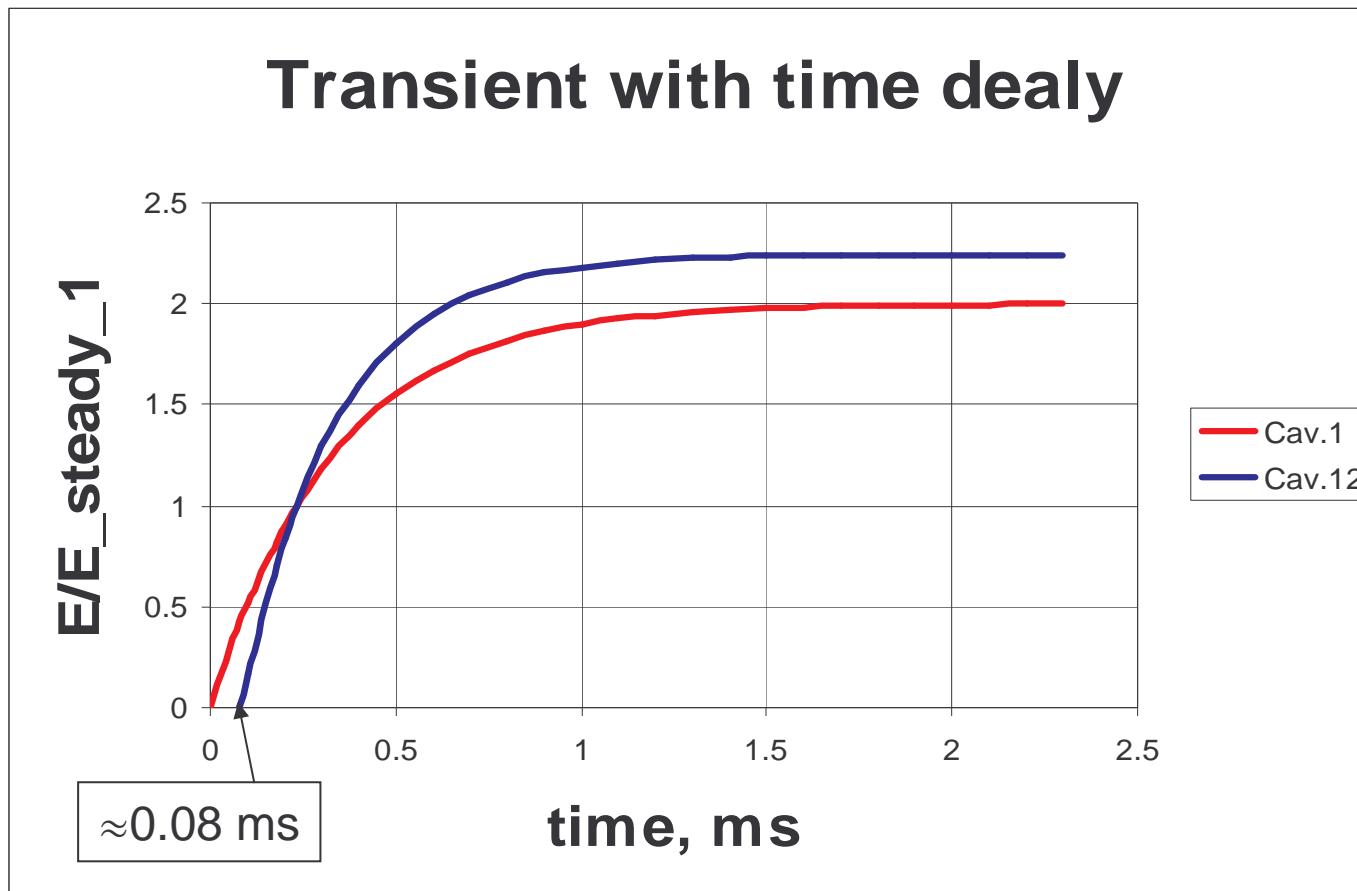
$$P_{\text{gen}} = P_{\text{beam}} + P_{\text{copper}}$$

There is no need to speed filling up -it's already fast enough. A cavity is filled up to nominal field level, then RF power is increased, when beam comes in.

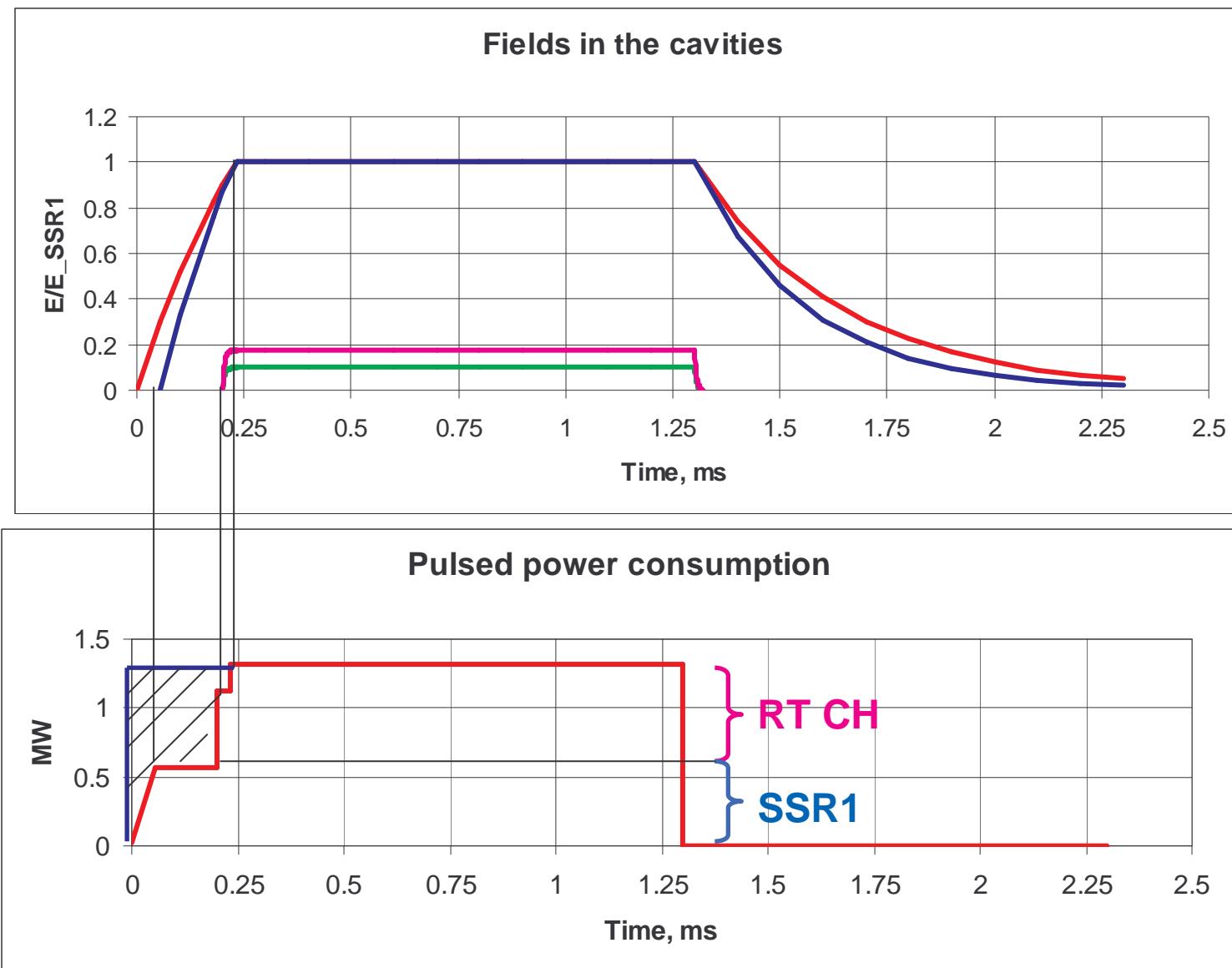
## Dealing with different fill times. Time delay.

Similar to Bob Kustom's option #2:

FVMs divert power from slower cavities until starting to charge them at a time that all cavities will reach nominal voltage simultaneously.

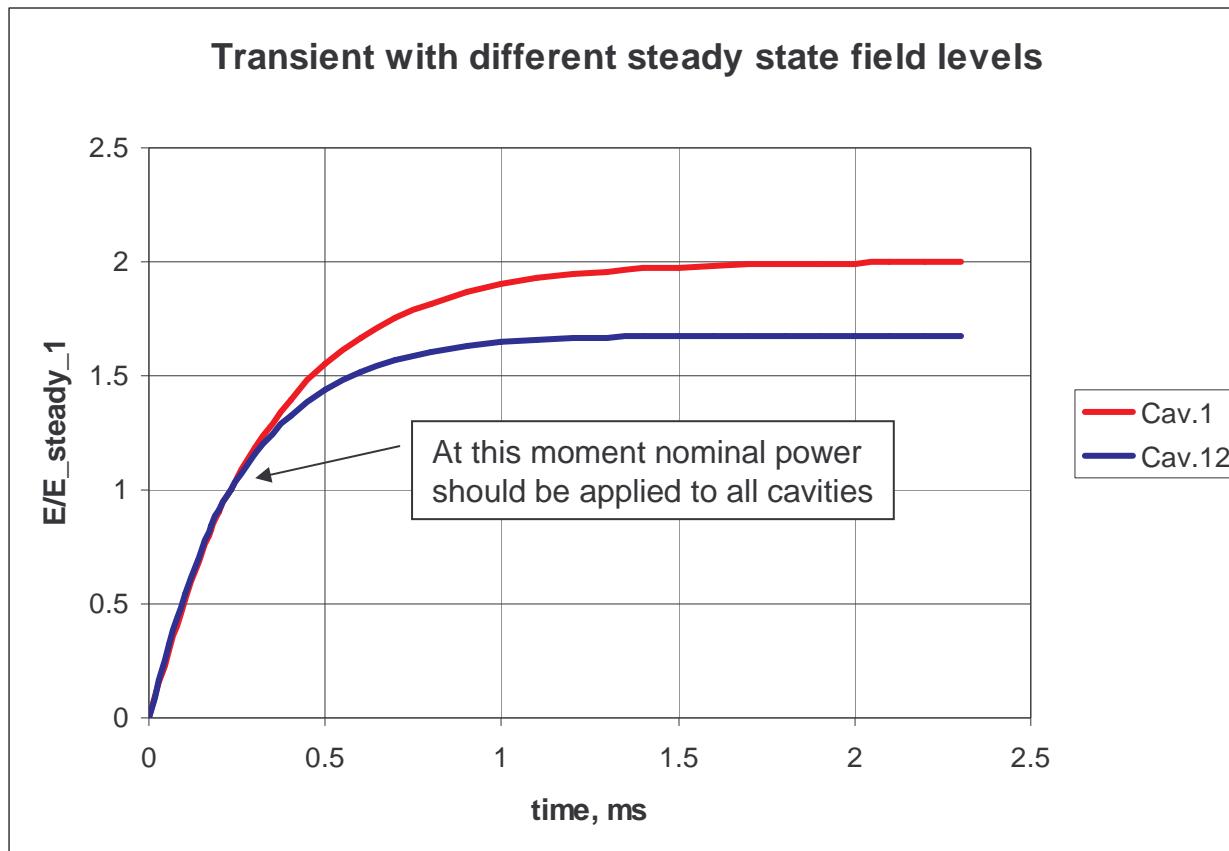


## Transient fields with time delay

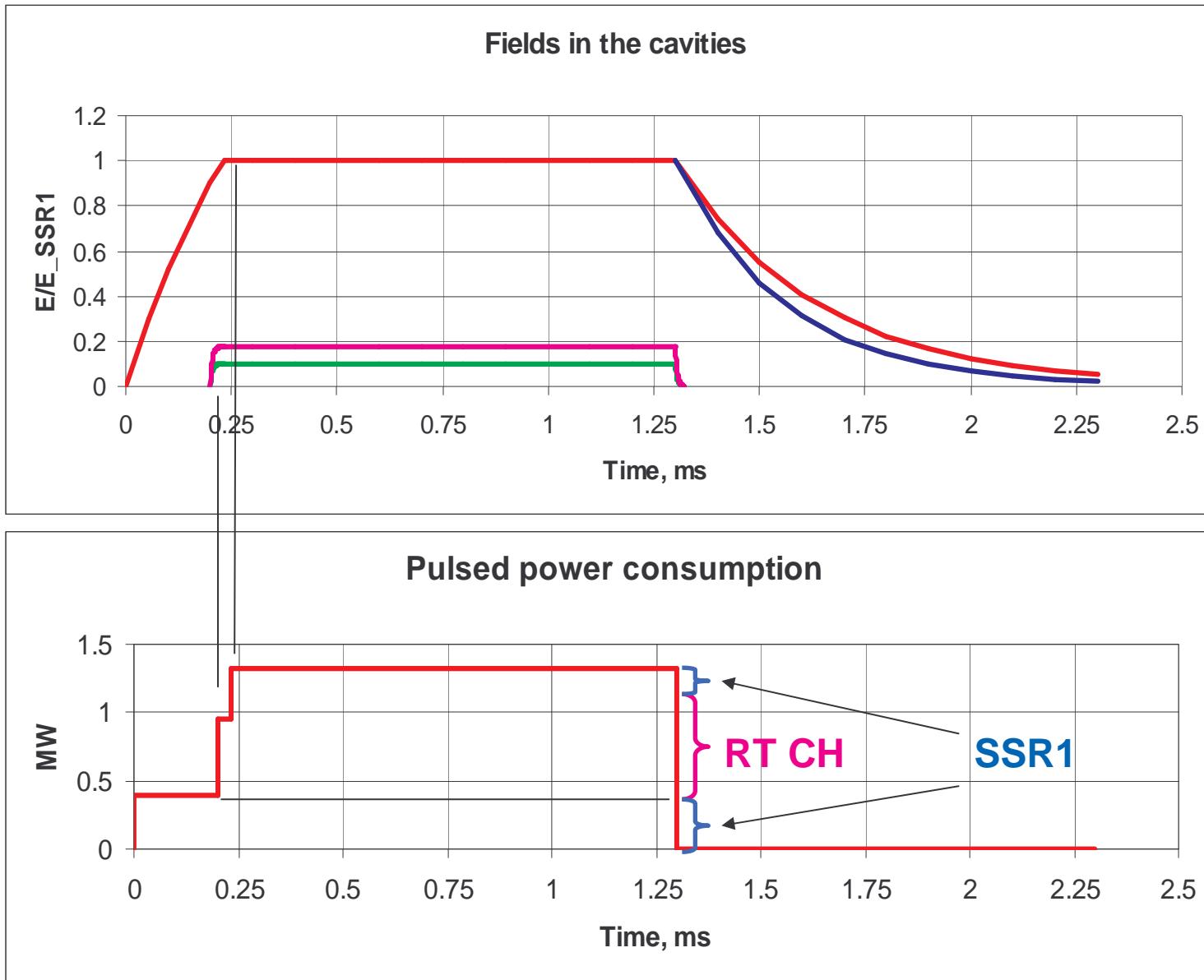


## Dealing with different fill times. Different initial amplitudes.

Using different initial amplitudes (relatively to nominal values) to equalize filling times. At a moment when all cavities reach their nominal field level the amplitudes have to be corrected to fit actual beam loading. It will be increased mismatching and power reflection during filling time.

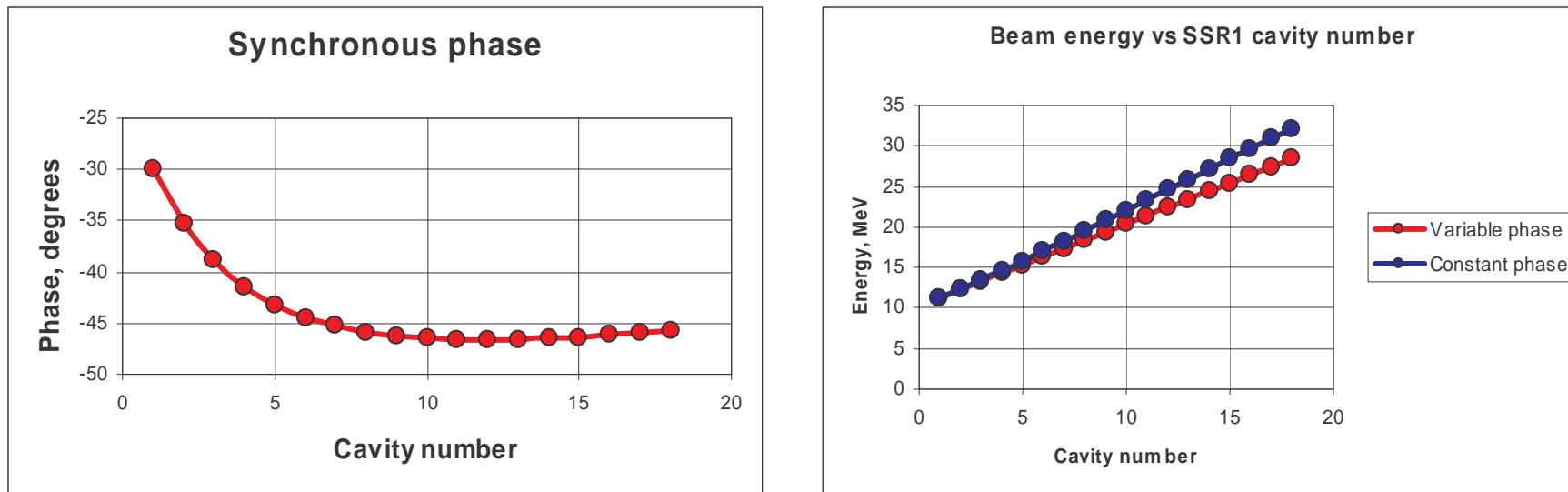


## Transient fields with different initial amplitude for SC



## Dealing with different fill times. Equalizing time constants by synchronous phase variation.

$$\tau = \frac{Q_L}{\omega}, \quad Q_L \approx Q_{ext}, \quad Q_{ext} = Q_{beam} = \omega W_{stored} / P_{beam} \quad \text{and} \quad P_{beam} = U_{eff} \cos \varphi_s I_{beam}$$

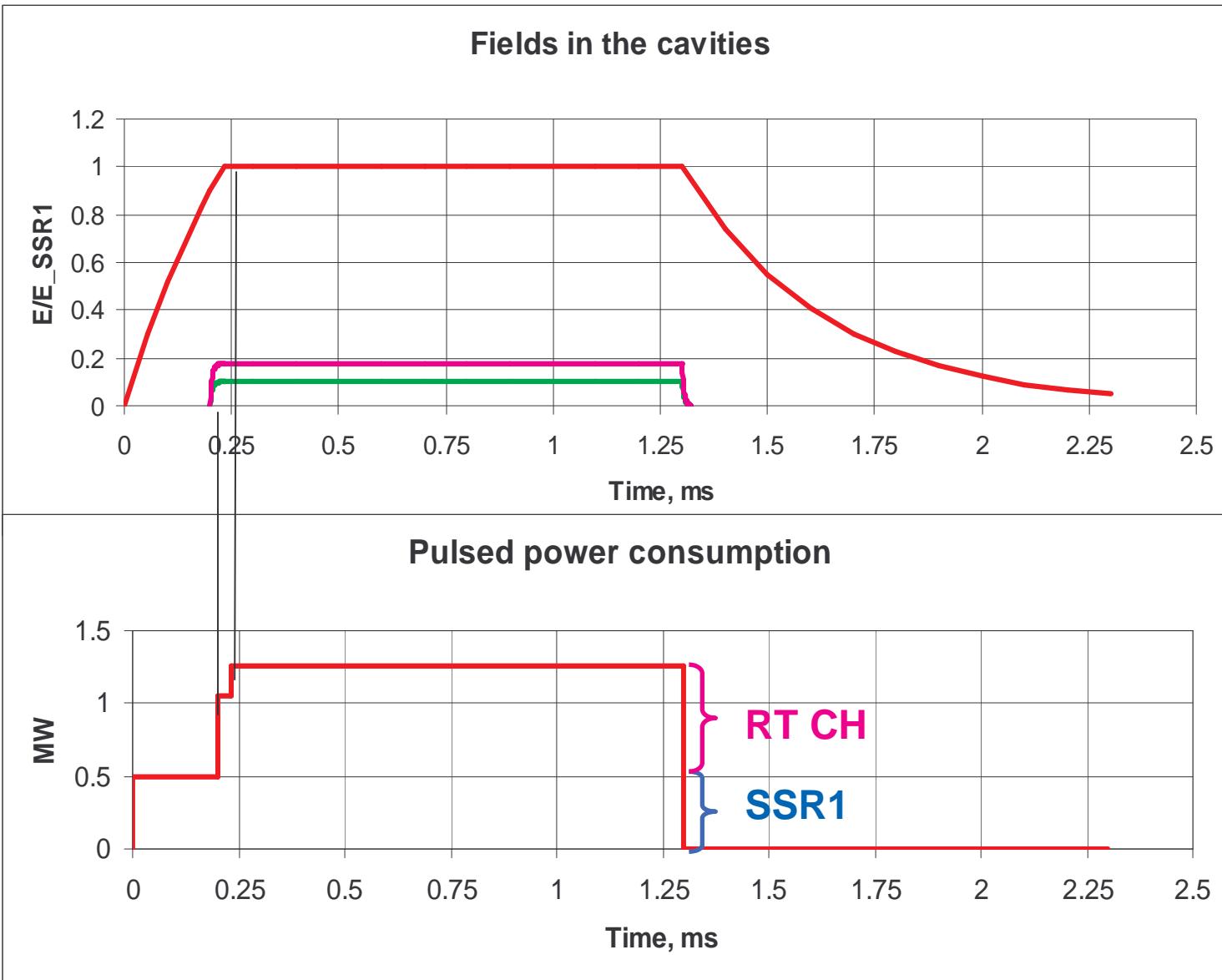


We get equal beam loading, equal time constants and equal coupling for all cavities. But we loose total energy gain.

To compensate energy drop an accelerating field may be increased by 15%.

**Note:** actually  $U_{eff} \cos \varphi_s$  should be equal for all cavities, but here I assumed  $U_{eff}$  constant for each cavity.

## Transient fields with equal time constant



## **Conclusion**

1. All options require rather complicated power modulating, splitting and damping.
2. Equal time constants for SSC may be a convenient option.